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Authors are range research coordinator, University of Nebraska, West Central Research and Extension Center, North Platte, NE 69101; and assistant professor, Range Science Department, Colorado State University, Fort Collins, CO 80523. Senior author was former research associate, Range Science Department, Colorado State University, Fort Collins, CO 80523.

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ABSTRACT

An orange sneezeweed (Helenium hoopesii) infested mountain park was sprayed with six herbicides at two rates of application in 1984. Standing crop of orange sneezeweed, graminoids, perennial forbs (excluding orange sneezeweed), annual forbs, and total were monitored in 1985 and 1986 to determine control of orange sneezeweed and the subsequent response of other plant community components. Orange sneezeweed standing crop was effectively reduced by all herbicide/rate combinations in 1985 and 1986. Graminoid response was limited in 1985 because of below average precipitation. However, orthogonal contrasts indicated an average of 630 kg/ha more graminoid standing crop in treated versus untreated plots. Picloram treatments yielded more graminoid standing crop in 1986 than all other treatments. Picloram (low and high rate) treatments averaged 3420 and 3750 kg/ha more graminoid standing crop than the control in 1986, respectively. Perennial forb standing crop was reduced to 10 and 20 kg/ha by the picloram (low and high rate) treatments in 1985, respectively. The high rate of clopyralid and 2,4-D plus dicamba also reduced perennial forb standing crop 240 and 235 kg/ha below the control in 1985, respectively. Perennial forbs had recovered in all treatments except the picloram treatments by 1986. Picloram (low and high rate) treatments produced 950 and 1080 kg/ha less perennial forb standing crop than the control in 1986, respectively. Annual forb and total standing crop were not affected by any treatment in 1985 or 1986.

Orange sneezeweed (Helenium hoopesii) is a stout, erect, herbaceous perennial that is native to upper elevations (2134 to 3810 m) in most of the western United States. Sneezeweed is a problem on these high elevation ranges because it causes severe and usually irreversible toxicosis in sheep (Marsh et al. 1921). Estimates of sheep losses to sneezeweed poisoning in Colorado range from 1 to 3% (Hesker 1982). A majority of the economic loss, however, may be attributed to ewes and lambs that ingest sublethal doses of sneezeweed. Because of the cumulative effects of the toxin in sneezeweed, ewes can become weakened and die during subsequent wintering or lambing seasons (Marsh et al. 1921). Lambs affected by sneezeweed will generally be lighter at weaning and show slower rates of gain in the feedlot resulting in less return to both the producer and the feeder. Losses of wool and lower lambing rates have also been reported (Doran and Cassady 1944; Hesker 1982).

Sneezeweed infestations were first noted in the early 1900's at which time studies were undertaken to investigate the plant and possible control measures. Sneezeweed was found to reproduce prolifically by both seed and offshoots from adventitious buds on the rootstalks (Cassady 1940). The spread and abundance of sneezeweed has been related to soil disturbance such as pocket gopher (Thomomys talpoides) activity and the intensity of range use by cattle (Turner 1969). These factors, combined with the aggressive and persistent nature of sneezeweed, have led to the domination of many mountain plant communities by this species. These sneezeweed infestations not only pose hazards to sheep, but also reduce the productivity of more desirable range species through

competition for light, nutrients, and water.

Mechanical methods of sneezeweed control such as grubbing and mowing have met with little success because of resprouting from adventitious buds on the rootstalks (Marsh et al. 1921). Marsh et al. (1921) and Turner (1969) found that sneezeweed density and production decreased over time with reduced or exclusion of grazing. However, the time span to reach an acceptable level of range restoration would be too long so as to make this procedure impractical.

Doran (1951) conducted an extensive herbicide control study on sneezeweed in the late 1940's using different formulations and rates of 2,4-D. Results indicated that a 90% kill of sneezeweed could be expected when 4.48 kg ae/ha (4.00 lb ae/ac) of 2,4-D was applied to actively growing sneezeweed in the pre-bloom to full-bloom stage. However, 2,4-D also damages other forb species commonly associated with sneezeweed which leaves a treated area open to sneezeweed reinvasion unless a good cover of grass or desirable forb species can be quickly established. Because of the importance of forbs in sheep diets (Cook 1983), it would be advantageous to find a herbicide that is highly selective for sneezeweed, but in turn leaves a large number of desirable forbs. The desirable forbs would not only be beneficial to the sheep, but would provide more competition to sneezeweed and minimize the conversion to a grass dominated community.

Objectives of this study were to evaluate different herbicide/rate combinations on the control of orange sneezeweed and to determine subsequent plant community responses.

MATERIALS AND METHODS

The study site is in a mountain park (40°10'30"N and 107°28'W) located on the Bears Ears Ranger District of the Routt National Forest approximately 72 km southeast of Craig, Colorado. Mean elevation is 2745 m.

Average annual precipitation exceeds 51 cm with at least 60% falling as snow. Summer precipitation is characterized by frequent light afternoon showers. Mean annual temperature ranges from -1° to 4° C with an average frost-free period of 60 days or less.

Surface soils range from loams to clay loams that are generally deeper than 20 cm. They are dark brown to black because of high organic matter and are slightly acidic. The soils have a high natural fertility and a moderate to high water storage capacity which results in relatively high plant productivity. These soils are generally classified as cryoborolls.

The mountain park is a forb-grass vegetation type dominated by a high percent of forbs. Orange sneezeweed is the dominate forb which comprises an average of 47% of the total plant composition by weight. Other perennial forbs contribute 28% to the composition and include western yarrow (Achillea millefolium), peavines (Lathyrus spp.), tall cone flower (Rudbeckia montana), American vetch (Vicia americana), northern bedstraw (Gallium boreale), lupines (Lupinus spp.), and soft cinquefoil (Potentilla pulcherrima). Annual forbs contribute only 5% and are comprised primarily of slenderleaf collomia (Collomia linearis), Douglas knotweed (Polygonum douglasii), and tarweed (Madia glomerata). Graminoids average 21% of the composition and include slender wheatgrass

(Agropyron trachycaulum), mountain brome (Bromus marginatus), Idaho fescue (Festuca idahoensis), Thurber fescue (Festuca thurberi), and carices (Carex spp.).

Three exclosures (36 x 43 m) were established in the mountain park in 1984. Thirty experimental units (25.3 m²) were laid out within each exclosure with 1.83 m alleys separating the units. Treatments were randomly assigned within an exclosure and consisted of 13 herbicide treatments. Six herbicides (dicamba, clopyralid, triclopyr, 2,4-D plus dicamba, picloram, and 2,4-D amine) at two application rates plus an unsprayed control comprised the 13 treatments. Chemical names and application rates are shown in Table 1. Treatments were replicated twice within each exclosure for a total of 26 experimental units (four experimental units/exclosure were unused).

Herbicides were applied on August 7 and 8, 1984 when orange sneezeweed was in the full-bloom stage. A Solo backpack pump was used for application with water as a carrier for all herbicides. Sunny conditions with calm winds prevailed at the time of application. No precipitation occurred in the 48 hours following treatment.

Current year's above-ground standing crop was estimated by the double sampling method using a 0.25 m² quadrat. Samples were collected by species with three quadrats per experimental unit being taken. Standing crop was expressed on an air-dry basis. Pre-treatment (1984) plus two years (1985 and 1986) of post-treatment data were collected. Pre-treatment datum was collected in late July and early August just prior to spraying. Post-treatment sampling was done in late August and early September following peak production. Data were combined into the

groups: orange sneezeweed, graminoids, perennial forbs (excluding orange sneezeweed), annual forbs, and total standing crop for analysis and discussion.

Data were analyzed using standard analysis of variance for the generalized randomized complete block design (Neter and Wasserman 1974). Each year of datum was analyzed separately to determine within year effects. The two years of post-treatment data were then analyzed as a split-plot in time to determine the effect of time on treatment response. Orthogonal contrasts were also used to test the overall effect of herbicide treated versus untreated areas. Duncan's multiple-range test was used to separate means when the F-test was significant. All differences are significant at $P \leq 0.05$ unless otherwise noted.

RESULTS AND DISCUSSION

Standing Crop Comparison Among Herbicides

Orange sneezeweed. Orange sneezeweed standing crop averaged 1500 kg/ha across pre-treatment plots in 1984 comprising 47% of the total plant composition. Sneezeweed standing crop was effectively reduced below levels of the control by all herbicide treatments in 1985 and 1986 (Table 2). The 2,4-D (low and high rate) and clopyralid (low rate) treatments were the only herbicide treatments that had measurable amounts (greater than 1 kg/ha) of sneezeweed standing crop in 1985. The herbicide treatments containing the largest amounts of sneezeweed standing crop in 1986 were the 2,4-D (low and high rate) and triclopyr (low rate) treatments (Table 2).

Although the 2,4-D treatments reduced sneezeweed standing crop,

appreciable amounts of sneezeweed were still being produced in 1985 and 1986 from both rates of application (Table 2). Since sneezeweed is a very aggressive plant, any treatment that leaves an appreciable amount of live sneezeweed could lead to an increased rate of reinvasion. However, it should also be noted that sneezeweed standing crop was 11 and 18 kg/ha lower in 1986 than 1985 in the 2,4-D treatments at the low and high rate, respectively (Table 2). During the same time period, sneezeweed standing crop increased 70 kg/ha in the control treatment. This difference may be related to increased competition from other plant species in the 2,4-D plots. This may mean that lower levels of control can be accepted when combined with rest or light grazing following herbicide treatment. These practices would allow remaining community members to increase and compete with sneezeweed in post-treatment years.

Timing of application also appears to be an important factor related to the effectiveness of 2,4-D on sneezeweed control, especially the amine formulation. Doran (1951) noted that the amine formulation of 2,4-D was slightly more effective for sneezeweed control when applied at the pre-bloom compared to the full-bloom stage. Because 2,4-D was applied at the full-bloom stage in this study, the effectiveness of sneezeweed control by 2,4-D may be lower than can be expected due to timing of application.

The across years analysis of sneezeweed standing crop revealed no year, year by block, or year by treatment effects. This indicates little change in the effects of the herbicides on sneezeweed standing crop between 1985 and 1986.

Graminoids. Analysis of 1985 graminoid standing crop indicated no differences among treatments (Fig. 1). Precipitation was below normal in 1985 which may have minimized the expression of treatment differences for the graminoids. Eckert et al. (1973) also reported that graminoid response was limited by below normal precipitation the year following 2,4-D application. Generally a large increase in graminoid standing crop would be expected because of improved water, nutrient, and light relations.

Although there were no differences in graminoid standing crop among treatments in 1985, the orthogonal contrast indicated greater graminoid standing crop in treated versus untreated plots. Graminoid standing crop averaged 1060 kg/ha across herbicide treated plots in comparison to only 430 kg/ha in the control plots.

Precipitation was normal to above-normal in 1986 and the effects of the herbicide treatments were more pronounced with varying degrees of graminoid response observed (Fig. 1). Analysis for 1986 indicated that the picloram (low and high rate) treatments had greater graminoid standing crops than all other treatments. The largest differences were among the picloram treatments and the control with 370 and 410% more graminoid standing crop in the low and high rate treatments of picloram, respectively. The dicamba (low and high rate), clopyralid (low and high rate), and 2,4-D plus dicamba (high rate) treatments also yielded more graminoid standing crop than the control. Graminoid yield in the triclopyr (low and high rate), 2,4-D (low and high rate), and 2,4-D plus dicamba (low rate) treatments were not statistically different from the control although these treatments appeared visually to have slightly

more graminoid standing crop than the control.

Analysis across years of post-treatment graminoid standing crop indicated a main effect of treatment in addition to a year by treatment interaction. The year by treatment interaction probably arose for graminoid standing crop because of no expression of treatment differences in 1985 followed by a pronounced expression of herbicide effects in 1986.

Perennial forbs. Treatment differences were observed in perennial forb standing crop in 1985 although the dry conditions suppressed perennial forb production (Fig. 2). The picloram (low and high rate) treatments had the greatest effect reducing perennial forb standing crop to only 10 and 20 kg/ha, respectively. The control produced 97 and 94% more perennial forb standing crop than the picloram (low and high rate) treatments, respectively. The high rate of clopyralid and 2,4-D plus dicamba also reduced perennial forb standing crop below the control by 71 and 69%, respectively. Although the dicamba (low and high rate), triclopyr (low and high rate), 2,4-D plus dicamba (low rate), and 2,4-D (low and high rate) treatments were not different from the control, they appeared to produce slightly less perennial forb standing crop (Fig. 2).

The excellent growing conditions in 1986 may have stimulated perennial forb recovery in some, but not all herbicide treatments (Fig. 2). The residual effects of the picloram treatments were still evident in 1986 which limited the recovery of perennial forbs in those treatments. The picloram (low and high rate) treatments produced 82 and 93% less perennial forb standing crop than the control, respectively. Because of the large reduction in perennial forb standing crop and the

apparent lasting effects, picloram at the rates tested would not be a preferred herbicide for use on forb dominated sheep range.

Clopyralid at the low rate did not affect perennial forb standing crop in 1985 when compared to the control (Fig. 2). However, doubling the rate of clopyralid to 2.24 kg a.i./ha reduced perennial forb standing crop below the control and the low rate of clopyralid. The clopyralid treatment at the low rate produced 71% more perennial forb standing crop than the high rate in 1985. Although perennial forb standing crop was not different between the rates of clopyralid in 1986, the effect of the high rate still appeared to be evident with the low rate of clopyralid producing 41% more perennial forbs than the high rate (Fig. 2). Because the high rate of clopyralid appeared to have a more severe effect on perennial forbs, this rate of application would not be recommended for use on mountain park sheep range.

Post-treatment analysis across years of perennial forb standing crop indicated a main effect of treatment in addition to a year by treatment interaction. The year by treatment interaction probably arose because of the recovery of perennial forbs in some, but not all herbicide treatments in 1986.

Annual forbs. Annual forb standing crop did not vary among herbicide treatments in 1985 or 1986. This would be expected since annual plants grow from seed every year, and therefore the herbicides would only be effective in altering annual forb standing crop in the year of application.

Annual forb standing crop did fluctuate across time with averages of 60 and 220 kg/ha in 1985 and 1986, respectively. Annual plant

populations are variable from year to year with populations being primarily regulated by environmental factors. Precipitation was below average in 1985 which is reflected in the annual forb standing crop.

Total standing crop. Total standing crop was not different among herbicide treatments in 1985 or 1986. Although total standing crop did not vary among herbicide treatments, there were shifts in the components of graminoids and perennial forbs among treatments. This suggests a release effect of the graminoids with herbicide control of sneezeweed and other perennial forbs. The release effect of graminoids being of approximately equal magnitude to the amount of perennial forb control since no differences were observed in total standing crop. This effect was also noted by Thilenius et al. (1974, 1975) in which forb dominated communities shifted to graminoid dominated after spraying 2,4-D without affecting total standing crop production. The only effect of the herbicide was in changing the structure of the plant community.

Total standing crop did vary between years, probably because of a precipitation effect, with averages of 1290 and 3720 kg/ha for 1985 and 1986, respectively.

CONCLUSIONS

Sneezeweed appeared to be susceptible to all herbicide/rate combinations tested with the 2,4-D treatments leaving the largest amount of sneezeweed standing crop. The dicamba, clopyralid, triclopyr, and 2,4-D plus dicamba herbicides effectively controlled sneezeweed and showed intermediate effects on perennial forb standing crop at the rates used in this study. Because sneezeweed was effectively controlled by

the low rate of application of these four herbicides, further research is needed with these herbicides to determine the lowest rate of application that will still give effective control. A lower rate of application would not only improve the economics of these herbicides, but might also reduce their effect on other perennial forbs which would be highly desirable on mountain park sheep range.

Sheep are selective for forbs as evidenced by the conversion of forb dominated communities to grass domination through the exclusive use of sheep grazing (Bowns and Bagley 1986). Because of their preference, it is important to determine the effects of herbicides on the various vegetative components of a plant community before trying to eliminate a single forb species. A shift in the structure of a plant community can lead to an undesirable shift in the diet composition of sheep or lead to increased utilization of the forbs that remain after spraying. This study indicated the herbicide/rate combinations of picloram that were used would be unacceptable for use on sheep range because of the almost total elimination of the perennial forb component. The 2,4-D treatments showed the least reduction in perennial forb standing crop. However, the 2,4-D treatments left a relatively large amount of sneezeweed standing crop in comparison to the other herbicides which could lead to an increased rate of reinvasion unless spraying is followed by rest or light grazing.

The graminoids are not only an important forage resource, but they also act as competitors against less desirable plants once they become well established. Marsh et al. (1921) and Turner (1969) observed a decrease in sneezeweed density following a subsequent increase in grass

density. Doran (1951) noted that provisions must be made to establish a good cover of grass following herbicide spraying of sneezeweed in order to suppress reinvasion. Results from our study indicated an overall increase in graminoid production in all herbicide treatments. The degree of graminoid release was approximately proportional to the degree of control of sneezeweed and other perennial forbs. Because of the overall increase in graminoids, it is likely that all herbicide treatments will lead to some degree of long-term sneezeweed suppression.

Treatment effects demonstrated in this study indicate that orange sneezeweed can be effectively controlled. Because of cost and concern for environmental consequences, however, sneezeweed control can only be recommended for specific problem areas where special management needs, e.g. staging area for gather, dictate reductions in poisonous plants. The future clearly dictates that understanding the role orange sneezeweed plays in the plant community with subsequent management strategies be devised to "manage" reductions in orange sneezeweed densities thereby reducing livestock poisonings.

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Table 1. Herbicides and rates of application for the orange sneezeweed study near Craig, Colorado.

Herbicides	Rates (kg a.i./ha)	
Common Name (Chemical Name)	Low	High
Dicamba (3,6-dichloro-o-anisic acid)	1.68	3.36
Clopyralid (3,6-dichloropicolinic acid)	1.12	2.24
Triclopyr ([(3,5,6-trichloro-2-pyridinyl) oxy]acetic acid)	1.12	2.24
2,4-D + dicamba (See 2,4-D and dicamba)	0.11 2,4-D + 1.12 dicamba	0.11 2,4-D + 2.24 dicamba
Picloram (4-amino-3,5,6-trichloropicolinic acid)	1.12	2.24
2,4-D amine ((2,4-dichlorophenoxy)acetic acid)	2.24	4.48

Table 2. Orange sneezeweed standing crop (kg/ha) by treatment for 1985 and 1986.

Treatment		Year	
Herbicide	Rate	1985	1986
Dicamba	Low	T[1]a[2]	2 a
Dicamba	High	T a	T a
Clopyralid	Low	11 a	T a
Clopyralid	High	T a	2 a
Triclopyr	Low	T a	46 a
Triclopyr	High	T a	0 a
2,4-D + dicamba	Low	T a	0 a
2,4-D + dicamba	High	T a	0 a
Picloram	Low	T a	0 a
Picloram	High	T a	2 a
2,4-D amine	Low	98 a	87 a
2,4-D amine	High	40 a	22 a
Control	----	578 b	648 b

[1]T = Trace (less than 1 kg/ha)

[2]Means in the same column followed by different letters are different ($P \leq 0.05$) as determined by Duncan's multiple range test.

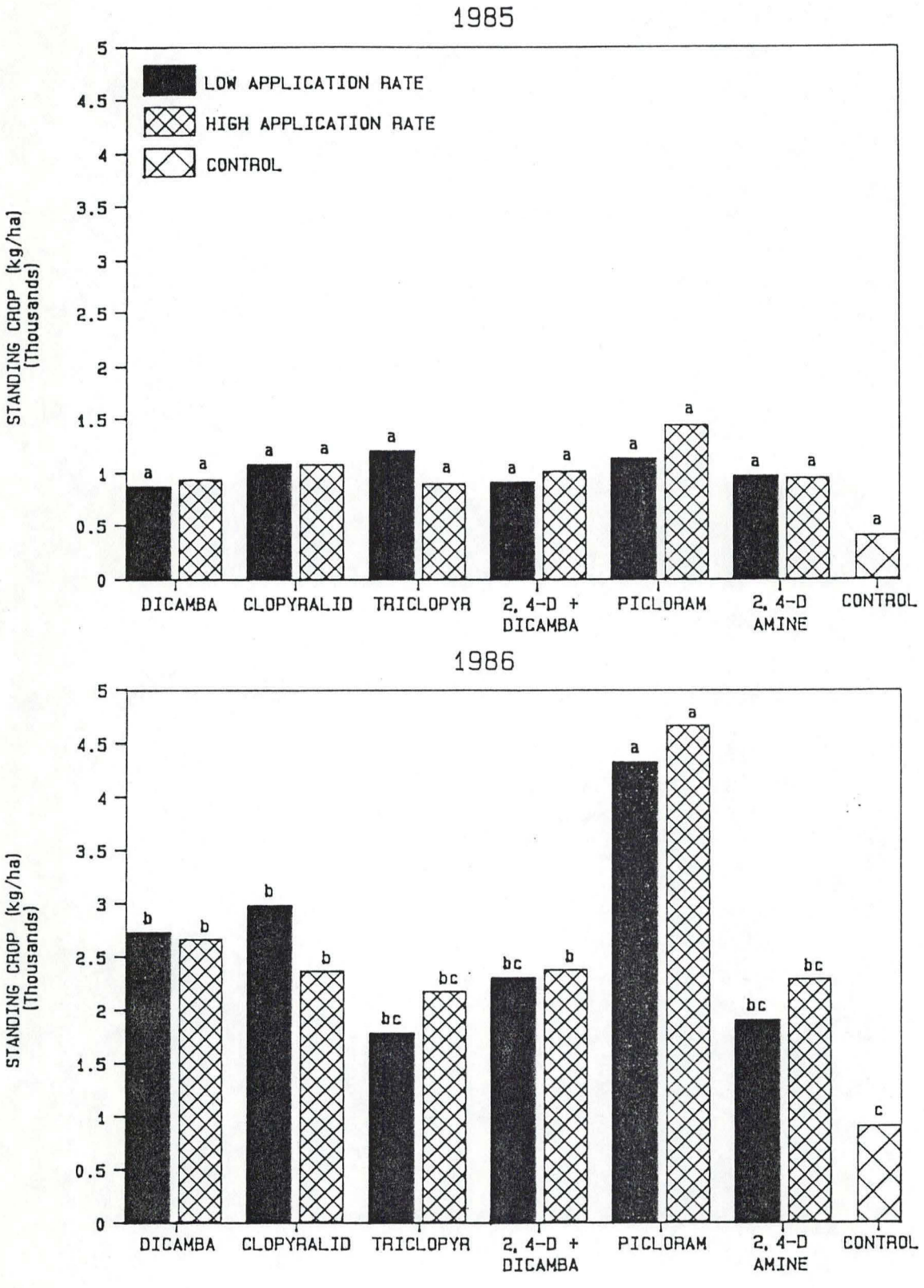


Fig. 1. Graminoid standing crop as affected by herbicide treatment in 1985 and 1986. Means within years with different letters are different ($P<0.05$) as determined by Duncan's multiple range test.

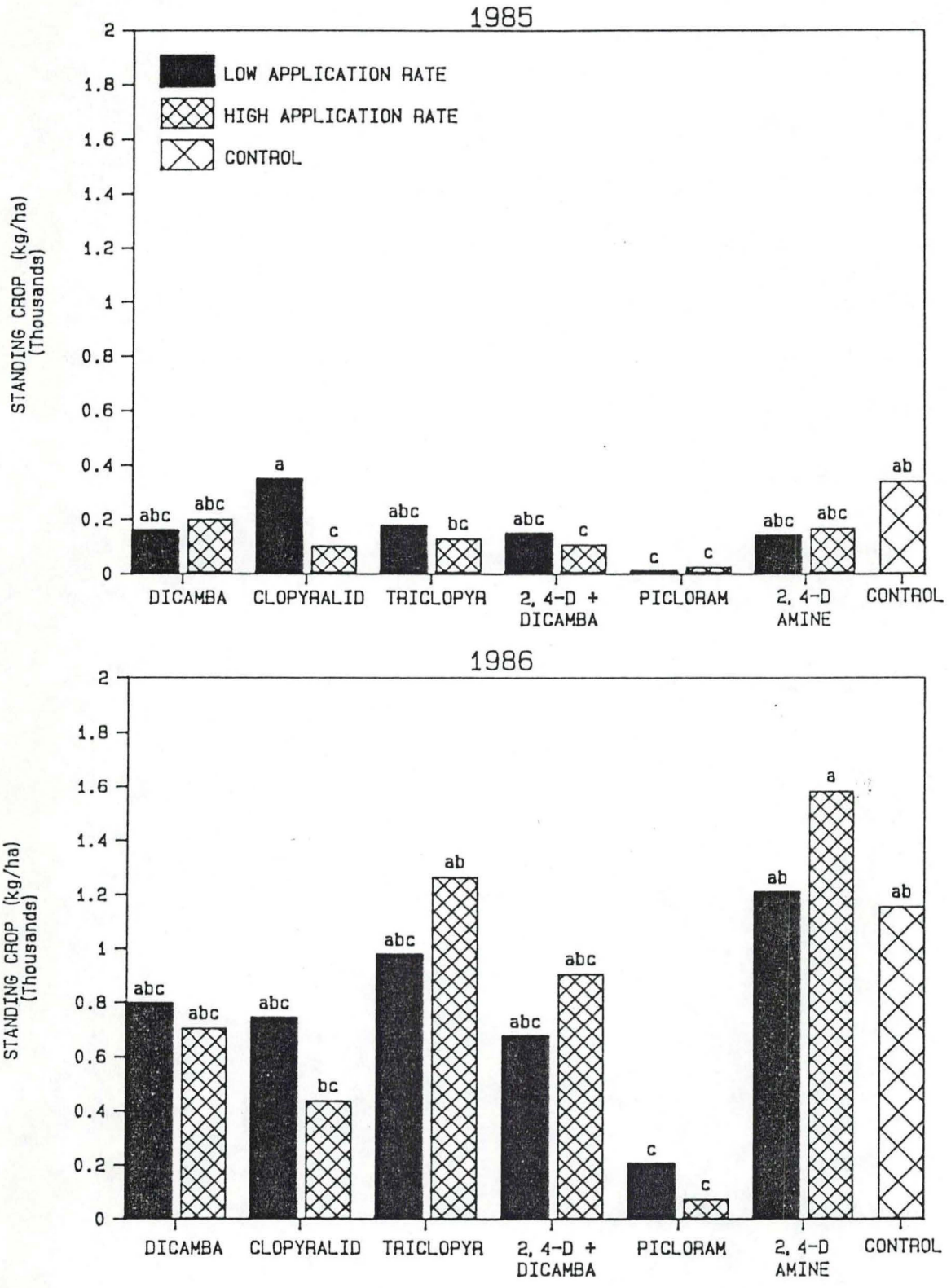


Fig. 2. Perennial forb standing crop as affected by herbicide treatment in 1985 and 1986. Means within years with different letters are different ($P<0.05$) as determined by Duncan's multiple range test.

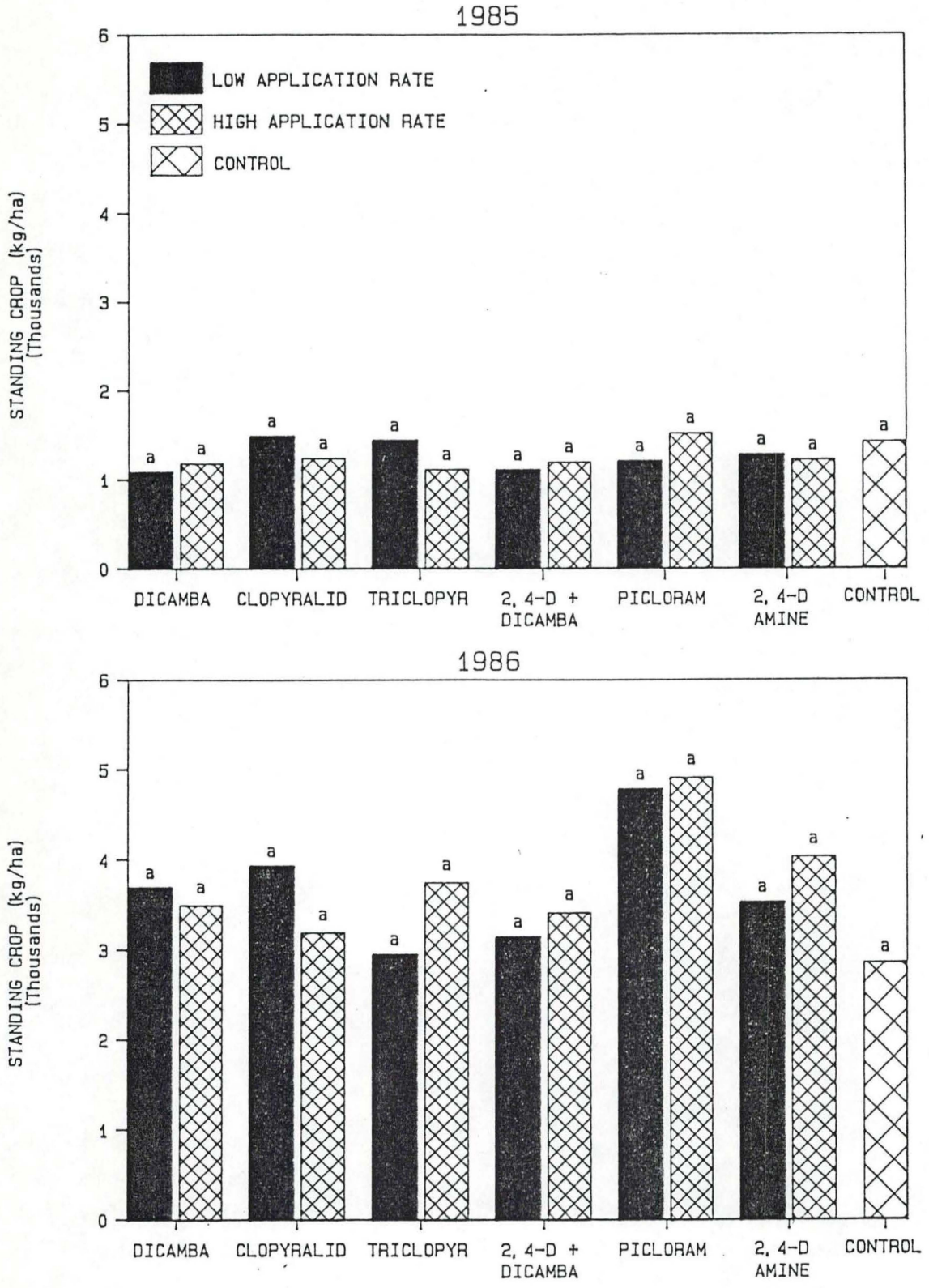
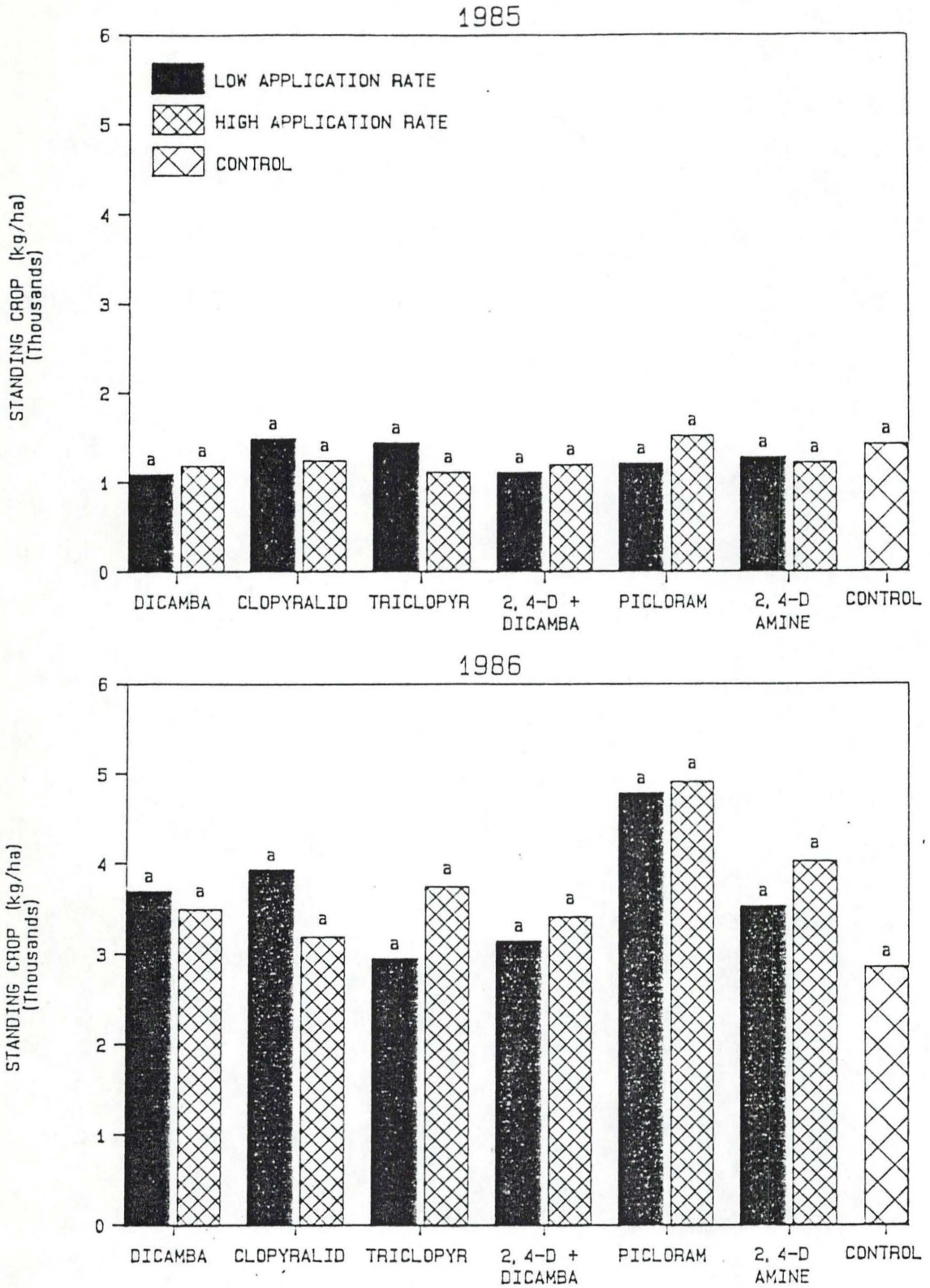


Fig. 3. Total standing crop as affected by herbicide treatment in 1985 and 1986. Means within years with different letters are different ($P<0.05$) as determined by Duncan's multiple range test.



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